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Method for producing a three-dimensional object

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The invention relates to a method for producing a three-dimensional object according to the preamble of claim 1.

In the method known as "layer manufacturing" a three-dimensional object is produced layerwise by applying and thereafter solidifying subsequent layers of an initially liquid or powdery material. Preferably, the solidification is made by a focused light beam in the form of a laser or the like which is directed to the places of the layer corresponding to the object and causes solidification of the material thereat. A method using a powdery solid material as medium for solidification is known from US 4,863,538.

An apparatus for carrying out the method using liquid or powdery material is known from DE 31 34 265.

A further apparatus for carrying out a method specifically using a powdery material is known from DE 43 00 178.

In order to obtain predetermined characteristics of irradiation and of the components mixtures of different powders are used, whereby the individual powders differ with respect to their thermal properties, such as the melting temperature and their rheological properties, such as their viscosity. However, the use of powder mixtures is disadvantageous in the following respects:

In a macroscopic powder mixture the individual grains of the powder have the macroscopic thermal or rheological properties of

the corresponding component of the mixture. When cooling after irradiating the layer using the laser beam a crystallization occurs in the individual regions (the powder grains) as a consequence of the uniformity and regularity of the polymer chains because, on a molecular scale, the polymers do not completely mix when irradiated. The crystallization causes a volume shrinkage of the component which may be more than one per cent. It is this volume shrinkage which is one of the greatest problems when producing three-dimensional models because it can be controlled only by an expensive and exact temperature control. However, such a temperature control can at most prevent the shrinkage of individual layers. In any case, shrinkage occurs when cooling the complete component. The degree of crystallization, i.e. the proportion of crystalline regions in the total volume, depends on the cooling rate. Since the cooling rate is again strongly dependent on the geometry, it differs e.g. strongly between thin walls and large filled volumes, respectively, the shrinkage by crystallization always represents an erratic factor of the precision of the component.

It is a further disadvantage that the powder may segregate or alter its mixture ratio during the process of application, processing or recovery. The danger of segregation is greatest for powder mixtures which differ in density, grain shape and grain size.

It is a further disadvantage of powder mixtures that the properties of the later component such as the thermal and mechanical characteristics, are determined by the component which is worse.

It is the object of the invention to provide a method for producing a three-dimensional object which allows to simplify the process control and to easily adjust and vary the desired properties of the later component in the starting material.

This object is achieved by a method according to claim 1. Further embodiments of the invention are defined in the subclaims.

A polymer blend is a molecular mixture of two or more polymers or copolymers. The mixture is made in the molten mass which is thereafter transformed into a powder. Thus, a powder grain contains different polymers in a predetermined mixture ratio. This is crucial for the homogeneity of the later component. The microscopical mixture forms a new phase which combines the properties of the mixture components and normally takes on average values. It is therefore possible to combine different property profiles on a molecular level such as brittle-soft or lowviscous-highviscous. The values for the glass temperature, the shear modulus and the viscosity can be continuously adjusted for polymer blends. Thus, the desired properties of the later component can already be adjusted in the starting material.

Since different chain structures exist in a polymer blend the crystallization is strongly impeded or is completely suppressed. Hence, the volume shrinkage caused by crystallization is also prevented. The volume shrinkage is completely eliminated for an amorphous polymer blend. This simplifies the process control and allows to produce models with higher precision using the same expense for the process.

Since the polymer blend is a mixture on a molecular level the powder cannot segregate or change its mixture ratio during processing or recovering the powder. Constancy of the mixture ratio is also ensured when using reused powder.

Further features and advantages of the invention will be apparent from the description of an embodiment with reference to the figure.

The figure shows an apparatus for carrying out the inventive method.

A tank 1 with an open top is filled with a polymer blend 3 in powdery form up to a level or surface 2. A support 4 having a substantially plane and horizontal support plate 5 is provided in the tank 1 in the region of the polymer blend 3. The support

plate 5 is parallel with the surface 2 and can be displaced and positioned upwards and downwards in a direction perpendicular to the surface 2 or to the support plate 5, respectively, by means of a not shown elevational adjustment device.

The object 6 is on the support plate 5 and constructed in a later described manner from a plurality of layers 6a, 6b, 6c and 6d each extending parallel with the surface 2 and with the support plate 5.

A not shown device for smoothing the surface 2 is arranged above the tank 1. This device can be formed for example as a drum or as a wiper.

An irradiation device 7 producing a focused light beam 8 is arranged above the tank 1. Preferably, the irradiation device 7 consists of a laser. The focused light beam 8 is deflected by a deflection device 9, for example a rotating mirror, and directed as a deflected beam 10 onto the surface 2 of the polymer blend 3 within the tank 1. A control unit 11 controls the deflection device 9 so that the deflected beam 10 strikes any desired point of the surface 2 of the polymer blend 3 within the tank 1.

In the method for producing the three-dimensional object a first step is to position the support plate 5 in the tank and to smooth the material existing above the support plate 5 using the not shown smoothing device in such a manner that the distance between the upper side of the support plate 5 and the surface 2 of the polymer blend 3 within the tank 1 exactly corresponds to the predetermined layer thickness. The laser beam 8, 10 produced by the laser 7 and controlled by the deflection device 9 and the control unit 11 irradiates this layer at predetermined points corresponding to the object, thereby sintering the polymer blend 3 and forming a solid layer 6a corresponding to the shape of the object. Further layers 6b, 6c and 6d are successively produced by lowering the support plate 5 by an amount corresponding to the respective layer thickness, smoothing the new layer for solidification and irradiating at the places corresponding to the object 6.

According to the invention it is preferred to use the following polymer blends: polyamide/copolyamide, polystyrene/copolyamide, PPE/PA blend (polyphenylenether/Polyamide) e.g. vestoblend, PPE/SB blend (polyphenylenether/styrene/butadieneblend), ABS/PA blend (acrylonitrile-butadiene-styrene/polyamide) or ABS/PC blend (acrylonitrile-butadiene-styrene/polycarbonate).

By selecting the mixture ratio of the polymer components in the polymer blend 3 the mechanical and/or thermal properties of the object (6) can be adjusted within large ranges.

## CLAIMS

1. Method for producing a three-dimensional object, wherein successive layers (6a, 6b, 6c, 6d) of the object (2) to be produced, which layers consist of a material curable in electromagnetic radiation, are solidified by action of an electromagnetic radiation one after the other, characterized in that the material is a polymer blend (3).
2. Method according to claim 1, characterized in that the polymer blend is used in powdery form.
3. Method according to claim 1 or 2, characterized in that the polymer blend comprises polyamide and copolyamide.
4. Method according to claim 1 or 2, characterized in that the polymer blend comprises polystyrene and copolyamide.
5. Method according to claim 1 or 2, characterized in that the polymer blend comprises polyphenylether and polyamide.
6. Method according to claim 1 or 2, characterized in that the polymer blend comprises styrene and butadiene.
7. Method according to claim 6, characterized in that the polymer blend comprises polyphenylether.
8. Method according to claim 1 or 2, characterized in that the polymer blend comprises acrylonitrile-butadiene-styrene and polyamide.
9. Method according to claim 1 or 2, characterized in that the polymer blend comprises acrylonitrile-butadiene-styrene and polyamide.
10. Method according to any of the claims 1 to 9, characterized in that the electromagnetic radiation is laser radiation (8, 9).

## ABSTRACT

In a method for producing a three-dimensional object, wherein individual layers (6a, 6b, 6c, 6d) of the object, which layers consist of radiation-curable material, are successively solidified by action of electromagnetic radiation (8, 10) a polymer blend (3) is used for the material. This allows to simplify the process control and to control the properties of the object (6) to be produced within large ranges by selecting the polymer blend or the mixture ratio of a polymer blend.

(Figure 1)

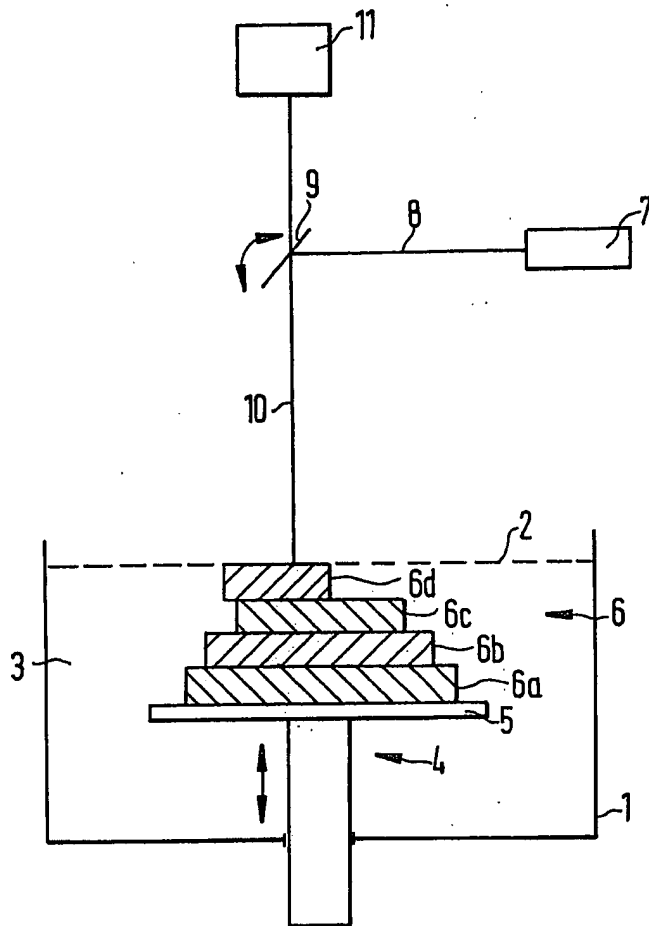


FIG. 1